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EFFECT OF THE ANGULAR POSITION OF THE SECTION OF A RING COWLING ON THE HIGH SPEED OF AN XF7C-1 AIRPLANE

By Melvin N. Gough

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Summary.

The tests herein reported were conducted by the National Advisory Committee for Aeronautics to determine the effect of the angular position of the section of a ring cowling on the speed of an airplane having a radial air-cooled engine.

An XF7C-1 airplane equipped with a special polygonal ring cowling, the angle of the section of which was adjustable on the ground through a range of 26 degrees, was tested with the cowling on each of 3 fuselage nose shapes. It was found that the high speed of the airplane could be increased as much as 12.4 m.p.h. upon the angular position of the ring cowling and the shape of the fuselage.

Introduction.

The now widespread use of radial air-cooled engine cowling has brought forth many modifications of the original N.A.C.A. type. In fact, the cowling which was intended to form a smooth streamline shape of the average fuselage with its projecting engine cylinders has, in some cases, been reduced to a small continuous ring above the cylinder heads. A cowling of the latter form, commonly known as the Townend Ring, has been developed elsewhere (Reference 1). Previous to the development of this ring cowling Townend found that by the use of small airfoils in the neighborhood of obstructions on a body, the air flow by the obstruction could be controlled and its relative direction governed. The interference effects so produced reduced the drag of the combination. A ring cowling of airfoil section placed above the cylinder heads of a radial air-cooled engine resulted.

It is readily seen that the section of the cowling should be placed at some angle to the relative airflow, which in turn depends upon the shape of the fuselage near the cowling. In order to determine the angular position that would give a minimum drag a ring cowling was constructed, the angle of which could be adjusted on the ground through a range of 26 degrees, and which could be used with each of 3 fuselage nose shapes.

The tests were conducted on an XF7C-1 airplane. The high speed, climb, and cylinder temperatures were obtained in flight with the cowling set at various angles with each of the fuselage nose shapes.

This work was done at the Langley Memorial Aeronautical Laboratory of the National Advisory Committee for Aeronautics. It is a continuation of the cowling work reported in References 2, 3, and 4.

Description and Method of Test.

The airplane used in these tests was a Navy single-seat shipplane fighter (XF7C-1), the fuselage lines of which were modified as will be noted. It was powered with a Pratt and Whitney "Wasp" engine and is completely described in Reference 4. A general view of the airplane with service fuselage (No.1) is shown in Figure I.

The propeller (Navy Drawing No. 3792, 9-foot) was set 20.5 degrees at the 42 inch radius. Throughout each series of tests the airplane was touched only for servicing and for changing the angle of the cowling.

The cowling was made in polygonal form of 9 individual airfoils of 17-1/4 inch chord and 13-inch span, one airfoil placed over the center of each cylinder. The airfoil section used was one designed to meet the structural and locational requirements. The airfoils themselves were constructed of 1/16-inch sheet aluminum bent around wooden forming ribs, the inner parts being cut away where they would normally interfere with the rocker boxes. To form a continuous ring cowling, the airfoils were faired together with filler pieces which were also made of sheet aluminum. The entire cowling with its supports weighed only 36 pounds.

The section and location of the cowling with respect to the engine are shown in Figure 2. The front mounting ring, which was the point about which the airfoils pivoted, was supported by radial members fastened to the engine crankcase cowling studs. The airfoils were supported at the rear by links which were adjustable in length and permitted angular motion of the airfoils about the front mounting ring. The adjusting links were secured to brackets extending from the exhaust flange studs and were originally designed to allow the cowling to be placed at approximately 2-degree intervals from -4.7 to -18.8 degrees. For one fuselage this range was insufficient and was increased from -4.7 to +6.4 degrees. The angles given are those formed by the chord of the airfoil and the thrust line. They are negative when the diameter of the cowling at the leading edge is smaller than at the trailing edge.

The fuselage lines at the nose were modified as shown in Figure 2. Front, three-quarter front, and side views of the variable angle cowling set at -4.7 degrees on the XF7C-1 airplane with service fuselage (No. 1) are shown in Figures 3, 4, and 5. For comparison, Figures 6, 7, and 8 are shown with the cowling at -4.7 degrees on No. 2 fuselage. Figure 9 is a side view of the cowling set at -8.8 degrees on No. 3 fuselage. The manner and amount by which the angle of the cowling could be changed may be seen from Figures 10, 11, and 12, which are front, three-quarter front, and side views of the cowling set at -18.8 degrees on No. 2 fuselage and Figure 13, which shows the cowling set at the other extreme, +6.4 degrees, on No. 1 fuselage. A better idea of the No. 2 fuselage nose shape may be obtained from Figure 14. The vertical deflectors between the cylinders may be noticed and were used with No. 2 and No. 3 fuselages.

The readings of all flight test instruments were recorded automatically. A recording altimeter and air-speed meter unit gave a continuous photographic record, while a motion picture camera gave an intermittent record of the readings of several instruments mounted in an automatic observer. The instruments consisted of two pyrometers, two electrical resistance thermometers giving the temperature of the atmosphere and of the thermocouple cold junctions, an indicating air-speed meter, and a tachometer. The pyrometers were connected successively with 18 thermocouples located on the engine cylinder heads and barrels.

The performance of the airplane in level flight and climb was determined with the cowling in various positions on Nos. 1, 2, and 3 fuselages. The angular range covered on Nos. 2 and 3 fuselages was from -4.7 degrees to -18.8 degrees and the data obtained showed that the maximum speed of the airplane was obtained with the cowling angle within that range. On No. 1 fuselage, however, the range was insufficient, so the adjustment was extended to +6.4 degrees. In general, the flight tests were conducted as follows:

1. Level flights were made at about 30 feet altitude over a measured course. Two full throttle runs were made with and against the wind, each time of transit being measured with a stop watch by the pilot. Since the variation of high speed with angular change of cowling was expected to be small, all speed runs on any one fuselage except No. 1 between -4.7 degrees

and +6.4 degrees, were made on the same day under nearly identical atmospheric conditions.

2. Three full throttle 10 minute climbs at the air speed giving the best rate of climb were made on both No. 2 and No. 3 fuselages with the cowling in 3 positions, one being near that which gave the highest speed in level flight. The data were computed according to the Lesley Method given in Reference 5.

3. On the same flight, and after each climb, a 15-minute full throttle level flight at 1500 feet was also made. This was more than ample time for engine and oil temperatures to become constant.

The air-speed measurement is estimated to be accurate within ±1 m.p.h. The error involved in making cylinder temperature measurements was small, the instrument installation being similar to that used in Reference 3.

Results and Discussion

The results of this investigation are presented in Tables I and II and Figures 15 and 17. Table I shows the speed data obtained from the full throttle level flight tests. In Figure 15, the high speeds obtained are plotted as ordinates with the angle of cowling to the thrust line as abscissas. An individual curve is shown for each of the 3 fuselages. The high speed of the airplane with each of the fuselage shapes and no outer cowling, known from previous tests, is also indicated. It is evident from these curves that there is a position or range of positions over which the cowling is most effective, and further inspection reveals that on each fuselage the cowling could be set at such an angle that no increase in speed would be derived from its use.

Because of its polygonal shape, the results of the variable angle cowling should not be compared directly with those of other types of ring cowlings which have been tested (Reference 4). The presence of slipstream twist, etc., makes it appear safe to say that cowlings should be of smooth annular shape for best results.

The outstanding features can well be shown by the following chart, composed of data taken from the curves:

Fuselage No.	1	2	3
High speed - cowling in best position, m.p.h.	153.3	155.1	156.1
High speed - no outer cowling, m.p.h.	143.7	146.3	149.0
Speed increase due to cowling, m.p.h.	9.6	8.8	7.1
Angle of cowling - best position.	-3.0°	-6.8°	-8.0°
Range of angles for speed within 1 mile per hour of maximum.	0 to -6.5	-5 to -8.0	-5 to -10.5
Total angular range.	6.5	3.0	5.5

This table shows:

(1) The least gain was obtained on the fuselage shape which gave the best uncowled speed.

(2) By modifying the fuselage and adding the variable angle cowling, the high speed of the airplane was increased 12.4 miles per hour.

(3) Depending on the fuselage shape, there was a range of 5 degrees over which the maximum increase was obtained.

(4) The range of positions over which the increase in speed was within 1 mile per hour of maximum was greatest on No. 1 and least on No. 2 fuselage. No. 1 fuselage has the smoothest and most regular lines with No. 3 next best, which shows that the angular range over which there is a maximum drag reduction due to the use of cowling is determined by the shape of the fuselage.

Although not a part of the regular test, airflow studies in flight were made and the information obtained seems worthy of note. Silk strings, 4 inches in length and mounted on 2-inch posts were attached to the upper portion of the fuselage and outer cowling in various places that they might be observed during flight. Some were also tied to the trailing edge of the outer cowling. The strings gave evidence of the angle of the slipstream for any steady flight condition, and any slipping or skidding of the airplane could be detected immediately by the change of the angle of the air stream as indicated by the strings. In level steady flight, and regardless of the attitude of the cowling, the strings on the fuselage cowling were fairly steady and parallel to the cowling lines. Those attached to the trailing edge of the outer cowling and extending back over the slot aligned themselves parallel to the fuselage. This suggests that there is a band of air of constant thickness emerging from the slot and flowing parallel to the line of the fuselage.

There was also an opportunity to make a flight with the filler pieces removed from between the airfoils and with the cowling set at -10.8 degrees on the No. 2 fuselage. The strings gave evidence of a disturbed airflow. Those placed in the space between the airfoils were inclined outwards at about 20 degrees to the airfoil and were fairly steady but appeared to be in a fast stream of air. The strings on the trailing edge and tips, though extending backward in the same general direction as they do on a normal ring cowling, rotated and whipped violently. The high speed with this cowling condition was but 140 m.p.h. Thus it is seen that the flow with this type of cowling is even worse than with no cowling at all. With no outer cowling or with individual airfoils over the cylinder heads, it appears that there is a free flow of air between the cylinders, and the cylinders themselves set up a wake or region of disturbed air which would not exist with a streamline body having no projections on its surface. A continuous ring outer cowling can be used to limit the wake and prevent the divergence of air from the fuselage. We know also that outer cowling may be placed at such an angle that it directs the air where it would normally go without cowling, or into the body behind, in either case being ineffective.

Figure 16 is included to show the change in visibility effected by the use of the variable angle cowling set at -4.7 degrees on the No. 1 (Service) fuselage, as compared with that when no outer cowling is used.

The climb, or time altitude curves are shown in Figure 17. As little difference in climb was expected because of the small gain due to the cowling at climbing speeds, climbs were made with the cowling in but three positions on No. 2 and No. 3 fuselages. None were made on No. 1 fuselage.

The cylinder head and barrel temperatures at 18 points on the engine are given in Table II. The last 9 points are identical points on each cylinder, and all temperatures presented are the maximum obtained during the climbs and level flights. Difficulties experienced during the tests made it impossible to obtain these date for No. 1 fuselage. The purpose of taking and including the temperature data is to show that the cowling did not seriously impair the cooling under any condition.

Conclusions.

The high speed of an XF7C-1 airplane with radial air-cooled engine and polygonal ring cowling, was increased as much as 12.4 miles per hour, depending upon the angular position of the ring cowling and the shape of the fuselage near the nose.

The range over which the gain in speed obtained was within 1 mile per hour of maximum varied from 3.0 to 6.5 degrees, and the angular position of the cowling which gave the maximum speed varied from -3 to -8 degrees, both depending upon the shape of the fuselage near the nose.

On all of the fuselage shapes tested, and within the angular adjustment of 26 degrees, the cowling could be set at such a position that no increase in speed could be derived from its use.

When ring type cowlings are to be used, careful consideration must be given to the shape of the body over which the air is to be directed.

It does not appear promising to use a cowling composed of individual airfoils over the cylinder heads.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., October 14, 1930.

References.

1. Townend, H. C. H. : "Reduction of Drag of Radial Engines by the Attachment of Rings of Airfoil Section, Including Interference Experiments of an Allied Nature, with Some Further Applications." Reports and Memoranda No. 1367, 1929.

2. Weick, F. E. : "Drag and Cooling with Various Forms of Cowling for a Whirlwind Radial Air-cooled Engine." N.A.C.A. Technical Report No. 313, Part I, 1929. Part II, Technical Report No. 314, 1929.

3. Schey, O. W. and Biermann, A. E. : "The Effect of Cowling on Cylinder Temperatures and Performance of a Wright J-5 Engine." N.A.C.A. Technical Report No. 332, 1929.

4. Schey, O. W., Johnson, Ernest and Gough, M. N. "Comparative Performance Obtained with XF7C-1 Airplane Using Several Different Engine Cowlings." N.A.C.A. Technical Note No. 334, 1930.

5. Diehl, Walter S. and Lesley, E. P. "The Reduction of Airplane Flight Test Data to Standard Atmospheric Conditions." N.A.C.A. Technical Report No. 216, 1925.

Table I.

Full Throttle r.p.m. and Air Speed for Various Angles of Outer Cowling.

Angle of Outer Cowling to Thrust Line	No. 1 Fuselage Weight - 3024 lb.		No. 2 Fuselage Weight - 3076 lb.		No. 3 Fuselage Weight- 2934 lb.	
	Maximum r.p.m.	Average Maximum Speed	Maximum r.p.m.	Average Maximum Speed	Maximum r.p.m.	Average Maximum Speed
No Outer Cowling	1860	143.7	1890	146.3	1880	149.0
-18.8°	1850	141.3	1900	143.6	1880	145.4
-14.8°	1885	146.0	1935	148.0	1900	149.4
-10.8°	1910	150.6	1940	152.1	1925	155.4
-8.8°	1915	151.0	1955	152.8	1930	156.0
-6.8°	1920	152.1	1960	155.2	1935	156.4
-4.7°	1915	153.0	1950	153.5	1925	155.0
-2.4°	1920	153.5				
$+1.9^{\circ}$	1910	150.8				
$+6.4^{\circ}$	1865	143.1				

Table II.
Cylinder Temperatures (°F.) as Obtained in Climb and Level Flight with the Variable Angle Cowling.

	No. 2 Fuselage								No. 3 Fuselage					
	Maximum Temperatures during full throttle climb for 10 minutes.				Maximum Temperatures during full throttle level flight for 15 minutes at about 1500 feet altitude.				Maximum Temperatures during full throttle climb for ten minutes.			Maximum Temperatures during full throttle level flight for 15 minutes at about 1500 feet altitude.		
Cowling position	-4.7°	-8.8°	-18.8°	No outer cowling	-4.7°	-8.8°	-18.8°	No outer cowling	-4.7°	-10.8°	-18.8°	-4.7°	-10.8°	-18.8°
Atmospheric temperature at ground at start of flight	48	53	54	46	48	53	54	48	62	61	94	62	61	94
Location of Thermocouple														
Between fins 5 and 6 above base front of No. 1 cylinder	265	220	215	220	210	180	180	190		170	200		165	225
Between fins 2 and 3 above base exhaust side of No. 1 cylinder.	255	230	220	170	230	215	210	170	250	260	285	250	225	270
Between fins 5 and 6 above base exhaust side of No. 1 cylinder.	235	215	220	150	205	200	200	145	235	235	270	220	200	245
Between fins 11 and 12 above base exhaust side of No. 1 cylinder.	310	280	270	190	295	275	265	210	305	290	335	315	295	320
Rear of base of No. 1 cylinder, below fins.	340	335	340	300	340	325	300	290		260	290		275	330
Between fins 5 and 6 above base rear of No. 1 cylinder.	325	300	285	275	300	275	260	260		280	310		255	310

(Cont. on page 15.)

Table II. (Cont.)

Cylinder Temperatures (^{o}F.) as Obtained in Climb and Level Flight with the Variable Angle Cowling.

Atmospheric temperature at ground at start of flight	48	53	54	46	48	53	54	48	62	61	94	62	61	94
Location of Thermocouple														
Between fins 11 and 12 above base rear of No. 1 cylinder.	290	300	380	335	300	315	290	305		280	330		300	335
Between fins 3 and 4 above front spark plug in exhaust passage on No. 1 cylinder.	405	370	350	355	420	375	365	350		325	350		360	395
Embedded near rear spark plug on No. 1 cylinder.	435	425	395	395	445	415	415	400		345	395		450	440
Between fins 2 and 3 above spark plug on rear of No. 1 cylinder.	420	390	370	370	420	375	385	395		345	415		425	460
Same position on No. 2 cylinder.	360	340	525	325	430	365	405	345	365	360	415	425	415	415
Same position on No. 3 cylinder.	440	440	420	425	470	435	450	420		370	440		405	440
Same position on No. 4 cylinder.	360	365	565	345	395	340	340	380	435	415	455	455	435	445
Same position on No. 5 cylinder.	360	325	570	420	430	345	325	430		430	440		445	460
Same position on No. 6 cylinder.	315	275	305	355	375	365	330	395	450	445	460	480	455	440
Same position on No. 7 cylinder.	365	370	385	385	445	420	415	410	440	440	465	465	455	450
Same position on No. 8 cylinder.	460	430	415	385	475	425	425	395	480	460	470	470	460	450
Same position on No. 9 cylinder.	445	420	405	310	490	425	440	350	425	415	430	430	440	435

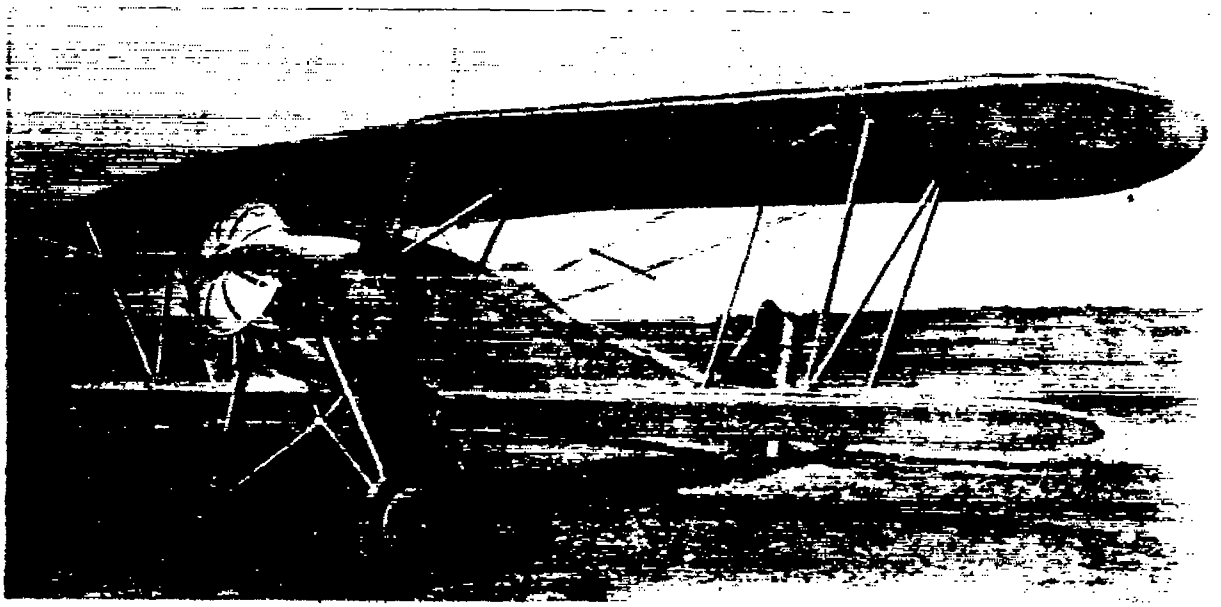


Fig.1 The Navy single-seat shipplane fighter XF7C-1 used in the tests.

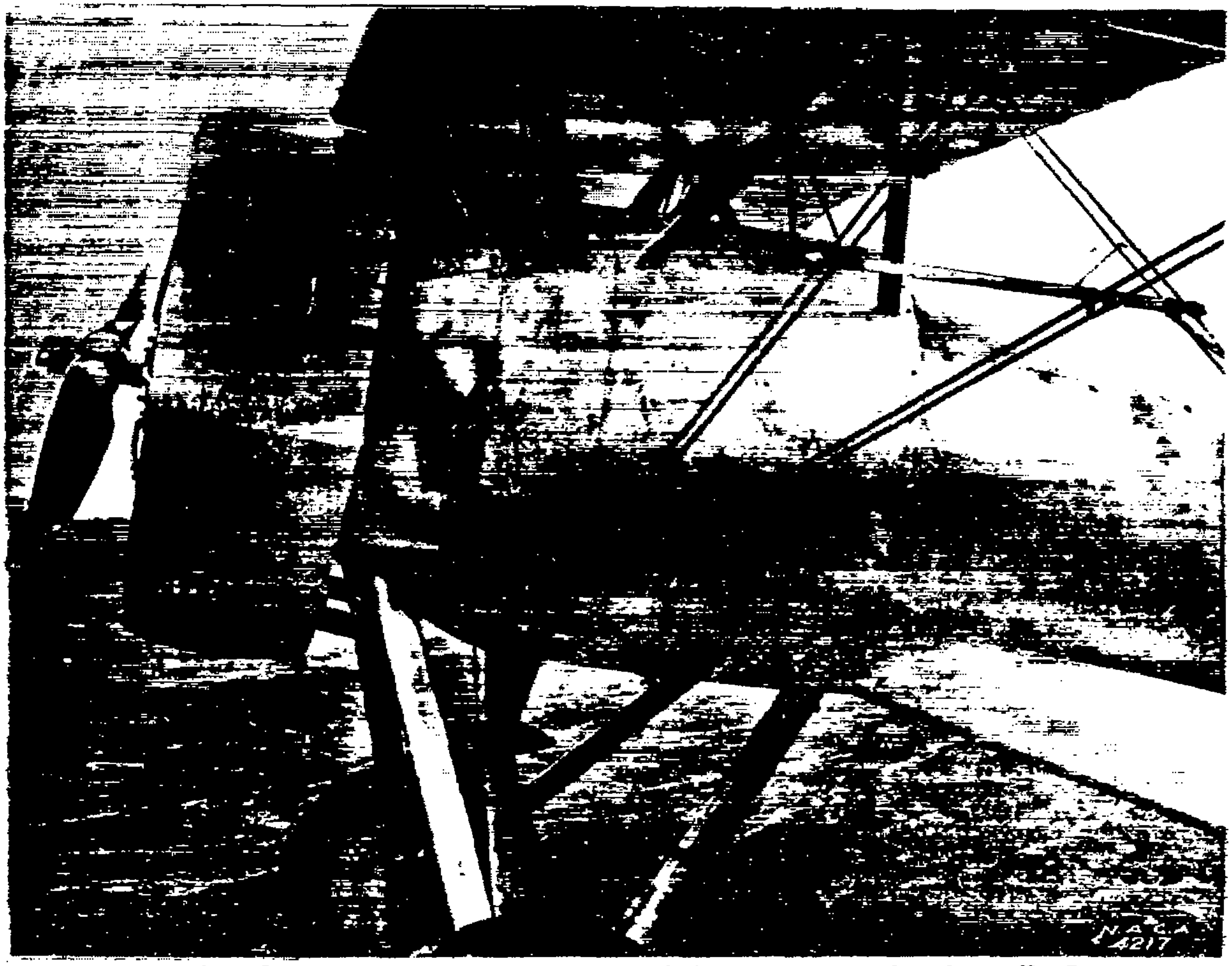


Fig.9 View of cowling set at -8.8 degrees on fuselage No.3

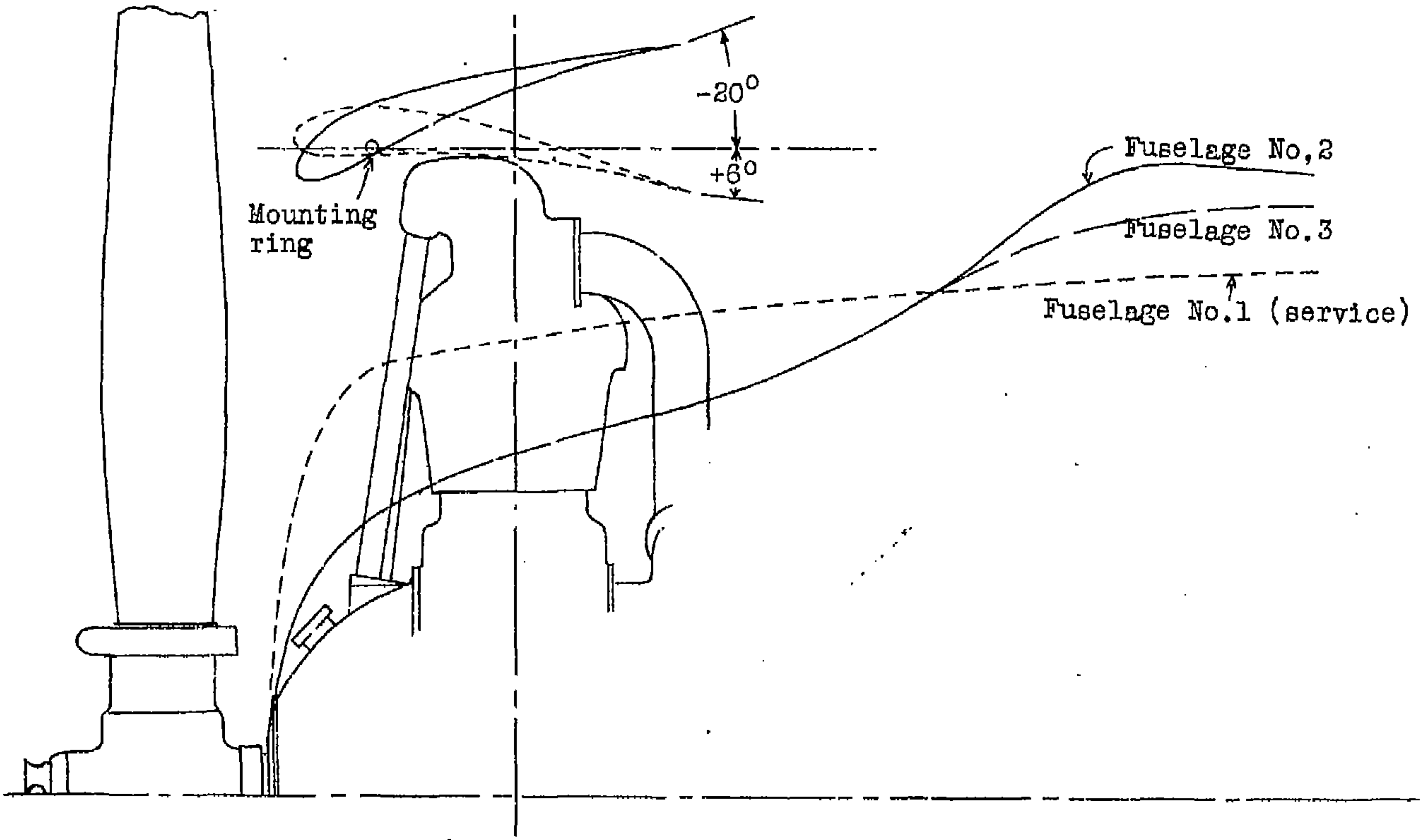
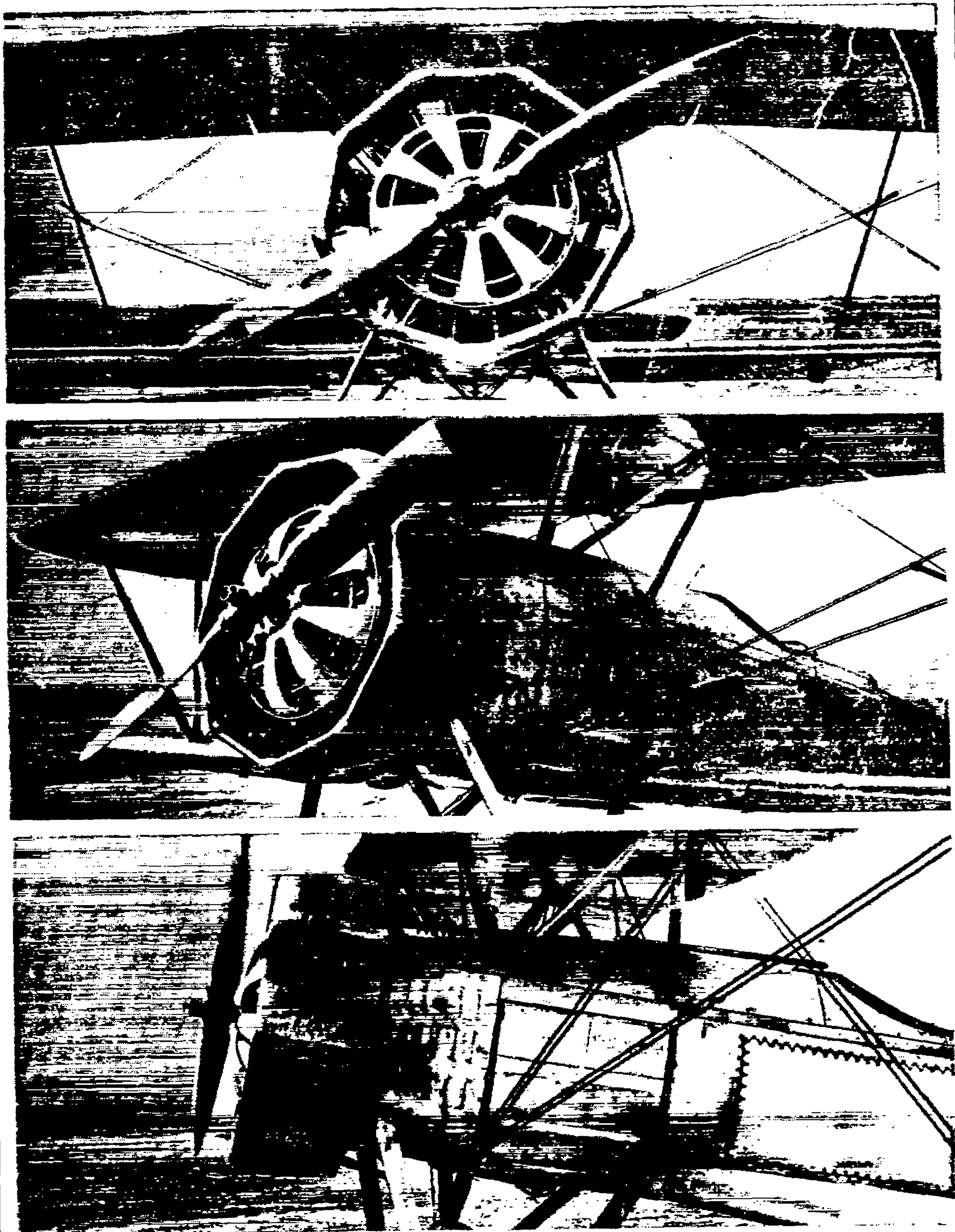
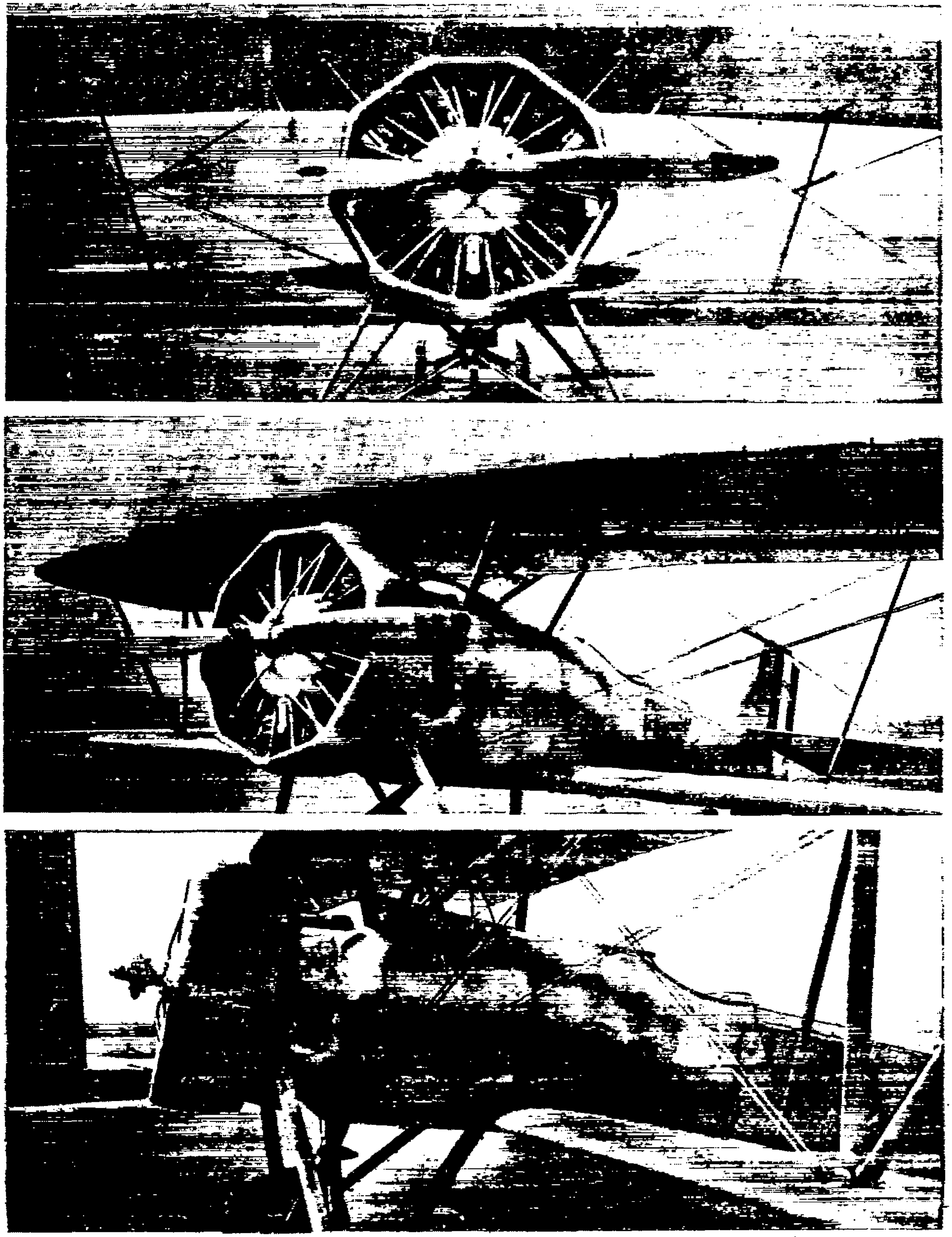


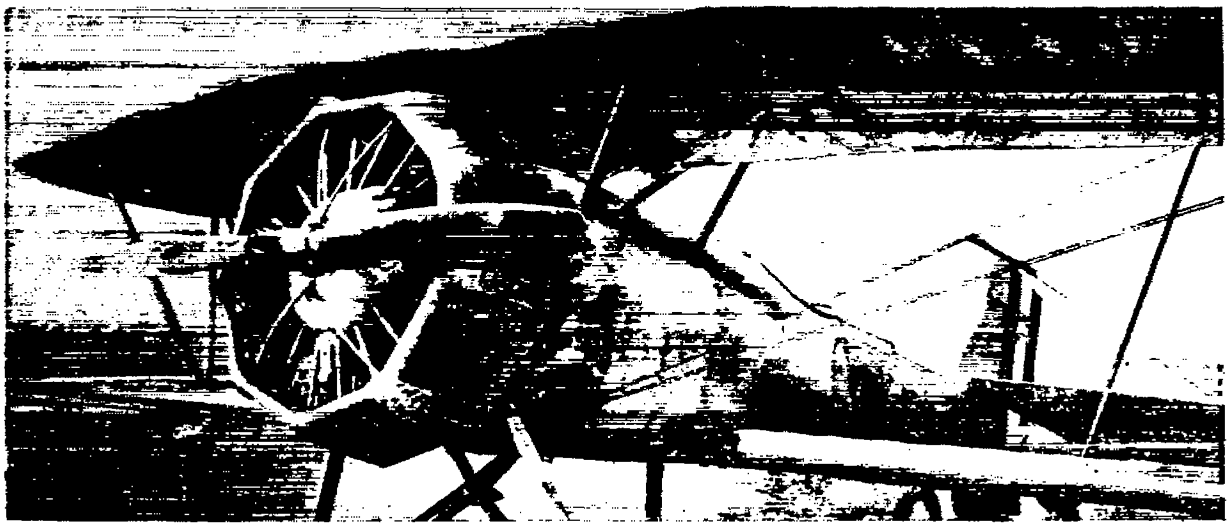
Fig.2 Variable angle cowling on XF7C-1 airplane.

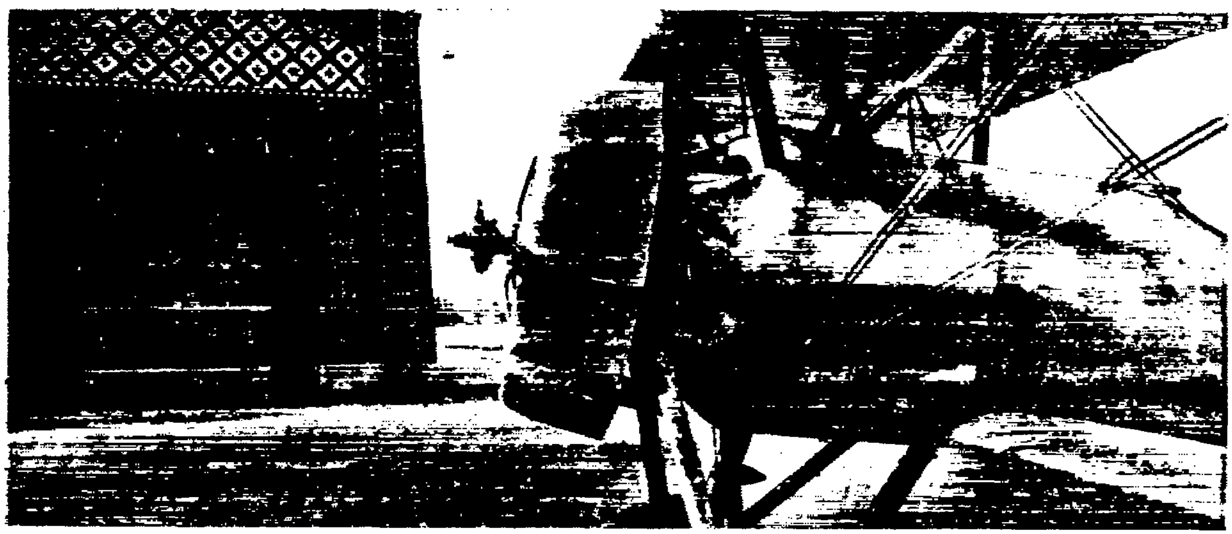


Figs.3,4,5 Views of cowling set at -4.7 degrees with service fuselage No.1.



Figs.6,7,8 Views of cowling set at -4.7 degrees on fuselage No.2.





Figs.10,11,12 Views of cowling set at -18.8 degrees on fuselage No.2.

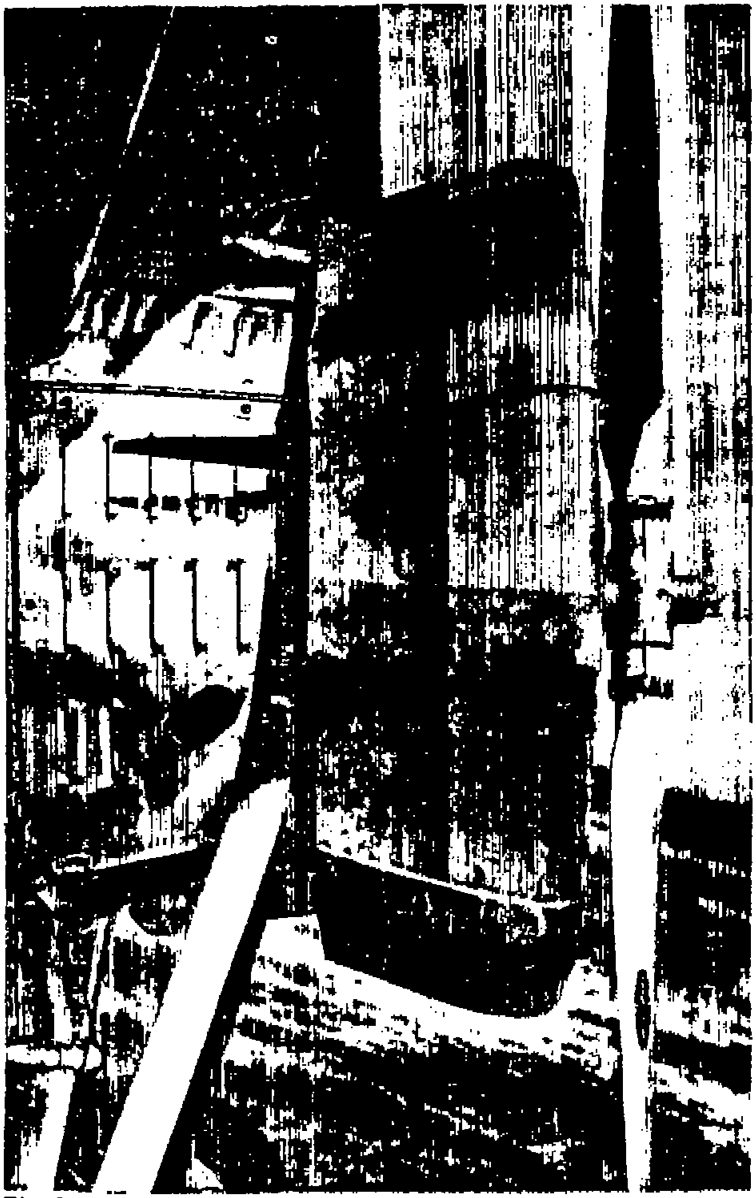


Fig.13 View of cowling set at +6.4 degrees on fuselage No.1

Fig.14 View showing nose shape of fuselage No.2

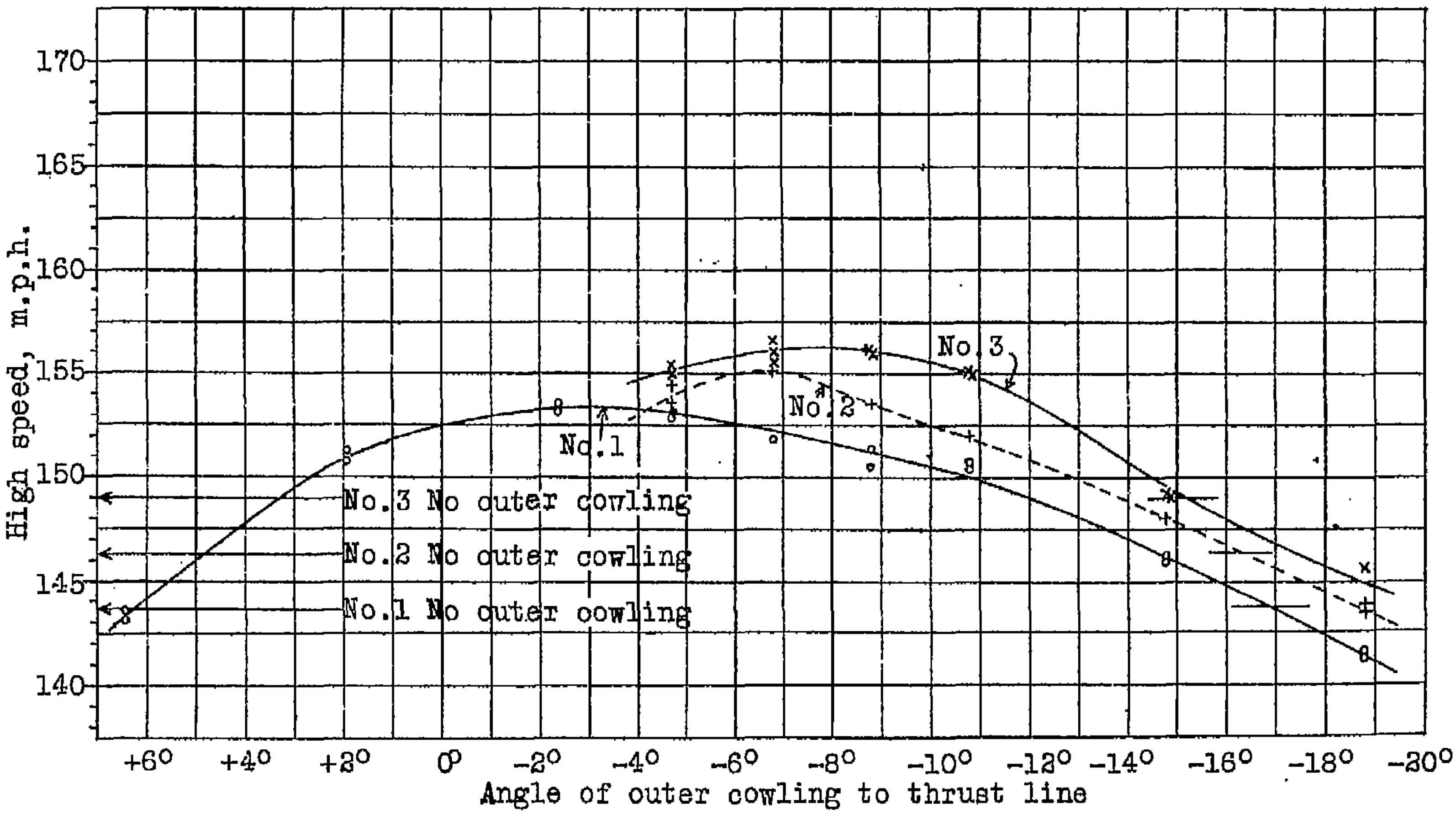


Fig.15 Variation of high speed with angle of outer cowling of XF7C-1 airplane.

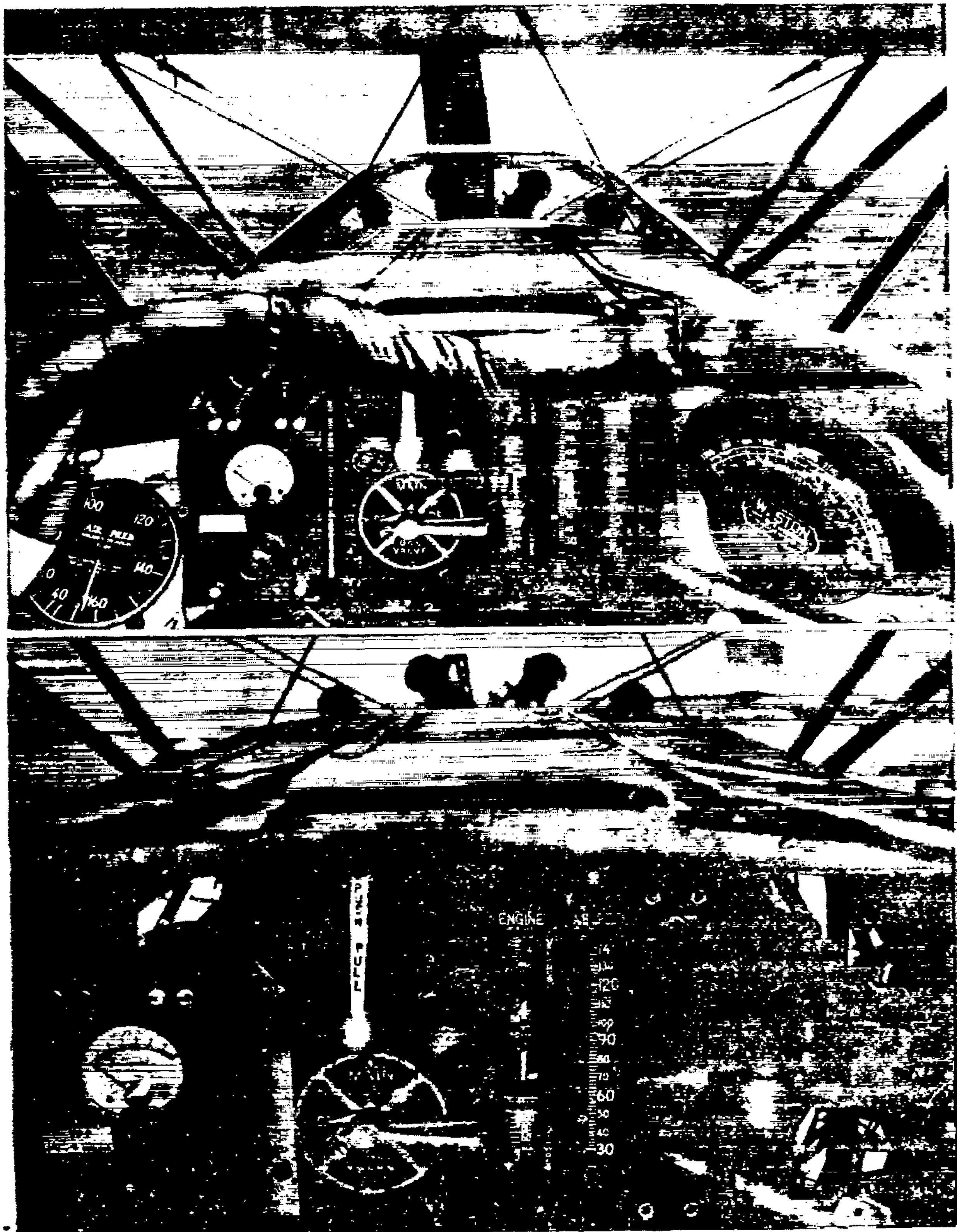


Fig.16 Views with No.1 fuselage showing visibility with and without cowling.

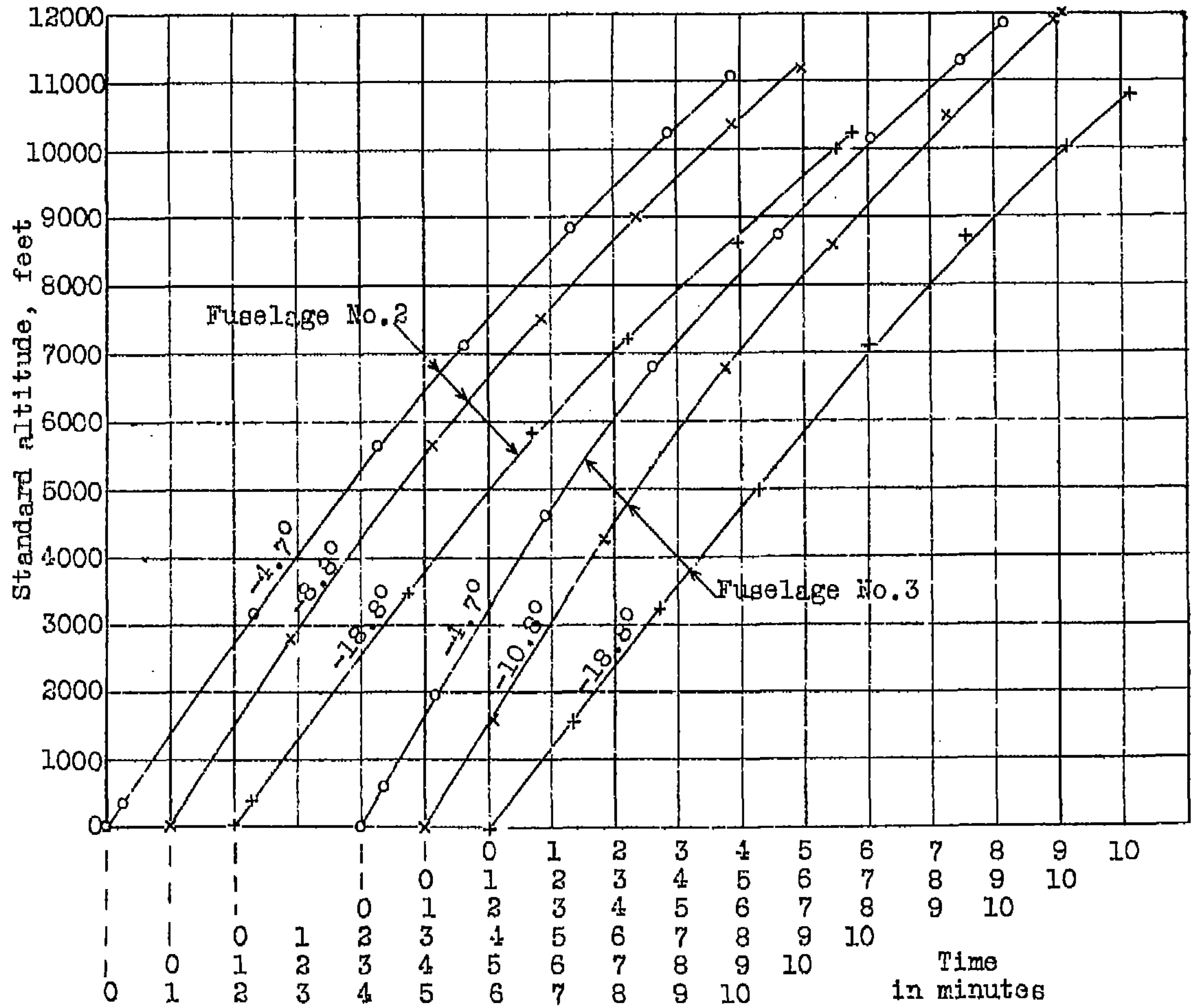


Fig.17 Full throttle climbs with variable angle cowling on XF7C-1 airplane.